# CARB LCFS Fuel Pathway Report

# Renewable Gasoline

Prepared For:


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# EXECUTIVE SUMMARY

The California Air Resources Board approved the original LCFS regulation in April 2009 as a discrete early action measure under the California Global Warming Solutions Act of 2006 (AB 32). In addition, the Board subsequently approved amendments to the LCFS in 2011, 2015, and in late 2018. For 2019 CARB has developed new, simplified calculators for determining the CI of transportation fuels. The new calculator for biodiesel and renewable diesel is much more flexible than the CA GREET 2.0 Tier 1 calculator. The new calculators are required to be used from January 1, 2019 and by the beginning of 2021 all plants were required to resubmit applications.

The new calculator presents the CI for multiple feedstocks simultaneously. It also presents a CI for naphtha and propane that are co-produced with the renewable diesel. The new calculator does require input data in a different format than the previous CA GREET 2.0 Tier 1 and Tier 2 calculators.

Phillips 66 Company ("Phillips 66") began production of renewable diesel fuel at its Rodeo Refinery in April 2021. Renewable diesel plants produce a small amount of naphtha, LPGs and light fuel gas a part of the production process. The CARB simplified calculator produces carbon intensities for the renewable naphtha and the renewable diesel at the same time. Phillips 66 have obtained provisional pathways for four feedstocks, two soybean oils, canola oil, and corn oil.

At the Phillips 66 refinery the renewable naphtha that is produced in the renewable diesel unit is co-processed with petroleum naphtha to produce renewable gasoline (RG). This report investigates the carbon intensity of the co-processing steps when soybean oil, canola oil and corn oil renewable naphtha is the feedstock.

There is no simplified calculator for co-processing renewable naphtha. A calculator has been developed which records all of the mass and energy flows and uses the CARB emission factors to calculate the gasoline carbon intensity.

The results for the Phillips 66 renewable gasoline pathways are shown in the following table.

**Table ES- 1 Carbon Intensity Summary**

| Stage | Emissions, g $CO_2$eq/MJ | | | |
|---|---|---|---|---|
| Feed | Soy Oil by barge | Soy Oil by rail | Canola Oil | Corn Oil |
| Renewable Gasoline | 32.90 | 29.93 | 42.63 | 29.51 |
| ILUC | 29.10 | 29.10 | 14.50 | 0.00 |
| Transportation | 0.30 | 0.30 | 0.30 | 0.30 |
| Tank to Wheel | 1.05 | 1.05 | 1.05 | 1.05 |
| Total | 63.35 | 60.38 | 58.48 | 30.86 |

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# 1. INTRODUCTION

The California Air Resources Board approved the original LCFS regulation in April 2009 as a discrete early action measure under the California Global Warming Solutions Act of 2006 (AB 32). In addition, the Board subsequently approved amendments to the LCFS in 2011, 2015, and in late 2018. For 2019 CARB has developed new simplified calculators for determining the CI of transportation fuels. The new calculator for biodiesel and renewable diesel is much more flexible than the CA GREET 2.0 Tier 1 calculator. The new calculators are required to be used from January 1, 2019 and by the beginning of 2021 all plants were required to resubmit applications.

The new calculator presents the CI for multiple feedstocks simultaneously. It also presents a CI for naphtha and propane that are co-produced with the renewable diesel. The new calculator does require input data in a different format than the previous CA GREET 2.0 Tier 1 and Tier 2 calculators.

Phillips 66 began producing renewable diesel fuel at its Rodeo Refinery in April 2021. This report accompanies a CARB Provisional Application for a Carbon Intensity determination for the renewable gasoline produced from the naphtha produced by the renewable diesel unit and co-processed in the refinery.

## 1.1 PHILLIPS 66 COMPANY

Phillips 66 has utilized a diesel hydrotreater ("Unit 250") at its Rodeo refinery to produce renewable diesel in an amount of up to [redacted] b/d. Renewable diesel production at Unit 250 began in early April 2021.

The Rodeo Refinery is shown in Figure 1-1.

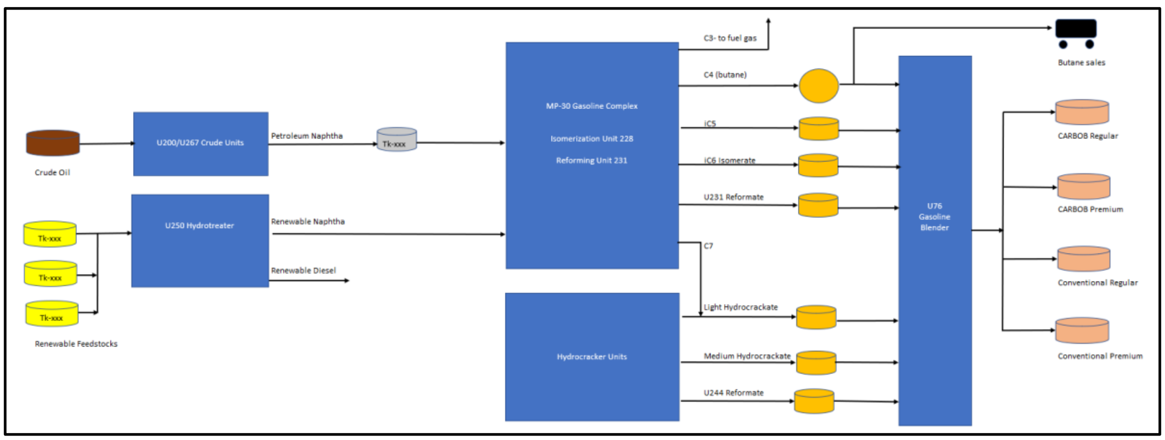
**Figure 1-1 Aerial View – Phillips 66 Company Rodeo Refinery**

The renewable naphtha is produced from soybean oil, canola oil and distiller's corn oil in the renewable diesel unit. The carbon intensity of these feedstocks is established in the provisional application.

The naphtha is co-processed with petroleum naphtha in the complex identified as MP-30 by Phillips 66. Determining the carbon intensity of co-processed streams is always more difficult than stand-alone facilities as the process inputs for each stream are comingled and can't be measured separately. The one advantage that this system has over other co-processing concepts is that both the fossil and renewable streams are pure hydrocarbon streams, there is no oxygen involved.

The renewable naphtha is first fractionated into several different streams by distillation and then some of the streams are isomerized and other reformed before final blending to produce renewable gasoline. The block flow schematic is shown in the following figure.

**Figure 1-2 Block Flow Schematic**




The quantity of renewable naphtha processed is measured with flow meters and the quantity of renewable gasoline produced is determined through modern carbon (Carbon 14) testing of the finished gasoline produced.

## 1.2 Model Set-Up

There is no simplified calculator for co-processing renewable naphtha. A calculator has been developed which records all of the mass and energy flows and use the CARB emission factors to calculate the gasoline carbon intensity.

# 2. FEEDSTOCK

The feedstock for the renewable gasoline is the renewable naphtha that is produced by the renewable diesel unit. The carbon intensities of the soybean oil, canola oil and corn oil renewable naphtha feedstock that are produced in the simplified calculator for the renewable diesel process are shown in the following table. Distribution, end use and ILUC emissions are itemized in the table below and subtracted from the naphtha CI in order to calculate the feedstock value for the renewable gasoline production process.

**Table 2-1 Renewable Naphtha CI**

| | Soy by barge | Soy by rail | Canola | Corn Oil |
|---|---|---|---|---|
| | g/MJ | g/MJ | g/MJ | g/MJ |
| Reported CI | [redacted] | [redacted] | [redacted] | [redacted] |
| Distribution emissions | [redacted] | [redacted] | [redacted] | [redacted] |
| End Use Emissions | -0.76 | -0.76 | -0.76 | -0.76 |
| ILUC | -29.10 | -29.10 | -14.50 | 0.00 |
| CI at plant gate | [redacted] | [redacted] | [redacted] | [redacted] |

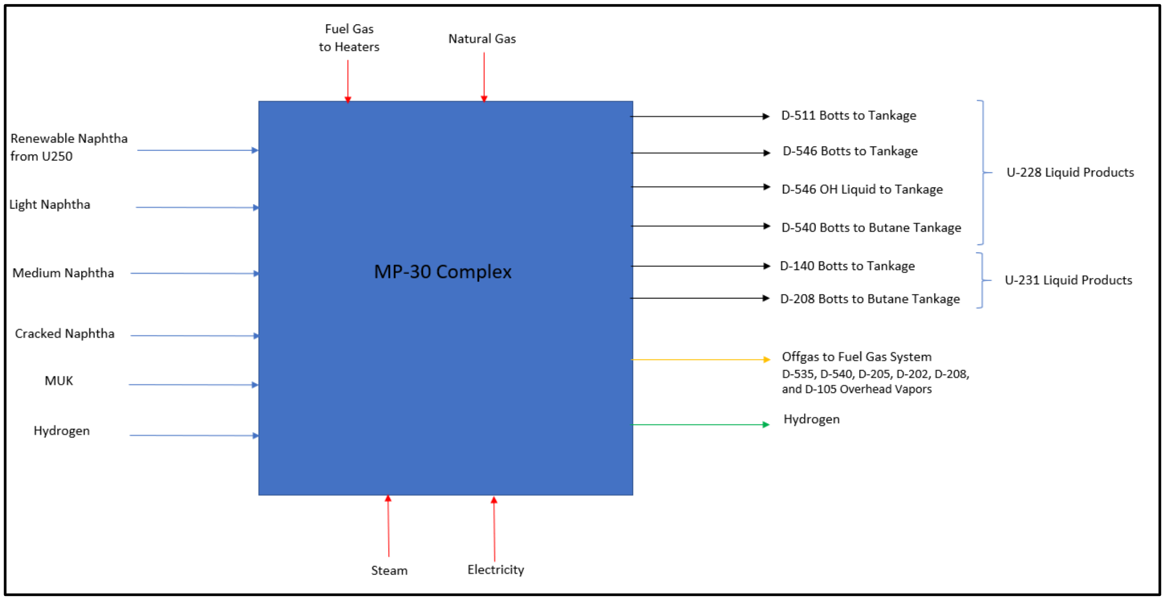
# 3. Renewable Gasoline Production

The renewable diesel plant produces a renewable naphtha stream as a co-product. At the Phillips 66 Rodeo refinery this product is used for further processing so that it can be used for gasoline blending. This analysis addresses the impact of the further processing on the carbon intensity of the renewable gasoline component. The volume of the renewable gasoline produced is determined by carbon 14 analysis.

## 3.1 Processing Operations

The renewable gasoline processing operations take place in the MP-30 Complex. The high level processing scheme is shown in the following figure.

**Figure 3-1 MP 30 Complex**




The gasoline MP-30 Complex is comprised of multiple units:

- U-229 Hydrotreater Unit
- U-230 Hydrotreater Unit
- U-231 Reformer Unit
- U-228 Isomerization Unit

Petroleum cracked naphtha from Tk [redacted], petroleum light naphtha from Tk [redacted], and medium naphtha from Tk [redacted] are the three liquid feeds sent to U-230 Hydrotreater. These feeds are hydrotreated to remove sulfur and nitrogen. U-230 reactor effluent is combined with the U-250 renewable wild naphtha which has already been hydrotreated at U-250. The calculations undertaken here will result in a conservative value since the hydrogen and energy required for the hydrotreating are also applied to the renewable feedstock, which doesn't require hydrotreating. Several fractionator towers split the liquid products so that the C5-C6 cut is sent to U-228 Isomerization, while the C7 cut is sent to gasoline blending and the C8+ cut is sent to U-231 Reformer.

U-228 isomerize the C5 and C6 molecules to increase their octane by producing isomerate, which is sent to gasoline blending. U-228 requires a small amount of makeup hydrogen as it saturates benzene.

U-231 upgrades the octane of its feed through the reforming reactors and also produces hydrogen. Liquid products from U-231 are butane (C4) and reformate which is sent to gasoline blending. Hydrogen produced by U-231 is sent to U-230 Hydrotreater, and excess hydrogen is used at the refinery for hydrotreating or hydrocracking in other units.

The overhead vapors are sent the fuel gas system. Any off-grade oil is sent to the slops system.

### 3.1.1 Mass Balance

Mass is mostly conserved through the processing unit, there is only a small mass loss through the unit. The mass balance is used for the carbon intensity calculations as it determines the gross up of the feedstock emissions. The mass of renewable gasoline that is produced and will generate LCFS credits will be determine by the total mass of gasoline produced and a measurement of the percent of modern carbon.

The masses into the unit for the 10 months that the unit has been processing renewable naphtha are summarized in the following table. In this table the hydrogen makeup is a pure hydrogen stream.

**Table 3-1 Mass into the MP-30 Complex**

| | Cracked naphtha | Light Naphtha | Med Naphtha | Renewable Naphtha | MUK | Liquid Mass | Hydrogen Makeup Total |
|---|---|---|---|---|---|---|---|
| | Pounds | | | | | | |
| May | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| June | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| July | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| August | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| September | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| October | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| November | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| December | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| January | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| February | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Total | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |

The information demonstrates that the unit operations do not vary significantly month to month and that the renewable naphtha represents [redacted]% of the feed to the unit. The concentration in the final gasoline will be even less as there are other refinery streams that are blended into the final gasoline product.

The liquid mass out of the complex is summarized in the following table.

**Table 3-2 Liquids out of the MP-30 Complex**

| | D-511 Botts to Tankage | D-546 Botts to Tankage | D-546 OH Liq to Tankage | D-540 Botts to Butane Tanks | D-140 Botts to Tankage | D-105 Botts to Tankage | D-202 Botts to Tankage | D-208 Botts to Butane Tankage | Total Liquid Products Out |
|---|---|---|---|---|---|---|---|---|---|
| | Pounds | | | | | | | | |
| May | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| June | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| July | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| August | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| September | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| October | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| November | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| December | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| January | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| February | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Total | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |

The complex also produces fuel gas and hydrogen. The fuel gas output is shown in the following table.

**Table 3-3 Fuel Gas Outputs**

| | D-535 OH Vapors | D-540 OH Vapors | D-205 OH Vapors | D-202 OH Vapors | D-208 OH Vapors | D-105 OH Vapors | Fuel Gas in Hydrogen Purge | Total Fuel Gas |
|---|---|---|---|---|---|---|---|---|
| | MM BTU | | | | | | | |
| May | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| June | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| July | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| August | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| September | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| October | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| November | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| December | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| January | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| February | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Total | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |

The complex is also a hydrogen producer. The hydrogen streams are not pure hydrogen so for reporting purposes they have been split into a fuel gas stream (shown above) and a pure hydrogen stream shown in the following table. The hydrogen content of the purge streams is the average over the reporting period.

**Table 3-4 Hydrogen Production**

| | U-228 H2 Purge | U-230 H2 Purge | U-231 H2 Purge | Total Hydrogen | Hydrogen wt% | Pure Hydrogen |
|---|---|---|---|---|---|---|
| | Pounds | | | | | |
| May | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| June | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| July | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| August | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| September | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| October | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| November | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| December | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| January | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| February | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |
| Total | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] | [redacted] |

The important factor with respect to the mass flow rates is the liquid product yield. There were [redacted] pounds of liquid feedstock input into the unit and [redacted] pounds of gasoline and butane produced for a liquid yield of [redacted]% over the 10 month period. During the winter months some of the butane is blended into the gasoline and the excess is sold as a product all year round.

This yield factor must be applied to the feedstock emissions (the wild naphtha) shown in Table 2-1. This is the feedstock CI divided by the yield, adjusted on an energy basis. Per the CA-GREET 3.0 model, the energy content of renewable gasoline is 18,590 BTU/lb. The energy content of the renewable naphtha per Rodeo Lab results is [redacted] BTU/lb. Therefore the yield adjustment on a energy basis is [redacted] x 18,590 / [redacted] = [redacted]. This is shown in the following table.

**Table 3-5 Feedstock Emissions**

| | Soy by barge | Soy by rail | Canola | Corn Oil |
|---|---|---|---|---|
| | g $CO_2$eq/MJ | g $CO_2$eq/MJ | g $CO_2$eq/MJ | g $CO_2$eq/MJ |
| Feedstock CI | [redacted] | [redacted] | [redacted] | [redacted] |
| Energy adjusted yield | [redacted] | [redacted] | [redacted] | [redacted] |
| CI based on product produced | [redacted] | [redacted] | [redacted] | [redacted] |
| Processing Impact to CI | [redacted] | [redacted] | [redacted] | [redacted] |

### 3.1.2 Fuel Gas Balance

The energy balance between the fuel gas produced and the fuel gas consumed in the unit produces the fuel gas balance shown in the following table. The fuel gas for steam production is calculated using the enthalpy of the steam and an assumed 80% LHV production efficiency. These values are all LHV values.

**Table 3-6 Fuel Gas Balance**

| | Fuel Gas Produced | Fuel Gas Consumed | Fuel Gas for Steam | Net Fuel Gas Produced |
|---|---|---|---|---|
| | MM BTU LHV | | | |
| May | [redacted] | [redacted] | [redacted] | [redacted] |
| June | [redacted] | [redacted] | [redacted] | [redacted] |
| July | [redacted] | [redacted] | [redacted] | [redacted] |
| August | [redacted] | [redacted] | [redacted] | [redacted] |
| September | [redacted] | [redacted] | [redacted] | [redacted] |
| October | [redacted] | [redacted] | [redacted] | [redacted] |
| November | [redacted] | [redacted] | [redacted] | [redacted] |
| December | [redacted] | [redacted] | [redacted] | [redacted] |
| January | [redacted] | [redacted] | [redacted] | [redacted] |
| February | [redacted] | [redacted] | [redacted] | [redacted] |
| Total | [redacted] | [redacted] | [redacted] | [redacted] |

### 3.1.3 Natural Gas

There is a small amount of natural gas consumed for pilot fuel for the heaters, but it is not measured. The maximum amount that could be used from the manufacturer's data has been calculated and used in the calculator.

**Table 3-7 Maximum NG Consumption**

| Month | Natural Gas Consumption |
|---|---|
| | MM BTU HHV |
| May | [redacted] |
| June | [redacted] |
| July | [redacted] |
| August | [redacted] |
| September | [redacted] |
| October | [redacted] |
| November | [redacted] |
| December | [redacted] |
| January | [redacted] |
| February | [redacted] |
| Total | [redacted] |

### 3.1.4 Electricity

The exact amount of electricity that is consumed in the complex is not measured but there are meters that will provide a conservative estimate of the power consumed. The values are conservative because thy include power demand that is not part of the complex.

The monthly power consumption is shown in the following table.

**Table 3-8 Monthly Power Consumption**

| Month | Power Consumption |
|---|---|
| | kWh |
| May | [redacted] |
| June | [redacted] |
| July | [redacted] |
| August | [redacted] |
| September | [redacted] |
| October | [redacted] |
| November | [redacted] |
| December | [redacted] |
| January | [redacted] |
| February | [redacted] |
| Total | [redacted] |

### 3.2 Summary

The GHG emissions of the renewable gasoline is calculated as the yield adjusted GHG emissions of the renewable naphtha plus the contribution from the electricity and natural gas used plus the emissions of the net consumption of fuel gas (calculated as natural gas) less a credit for the net production of hydrogen using the same emission factor for hydrogen that was used in the calculation of renewable diesel and renewable naphtha. These values are summarized in the following table.

**Table 3-9 GHG Emissions of Renewable Gasoline**

| Component | Soy by barge | Soy by rail | Canola | Corn Oil |
|---|---|---|---|---|
| | g/MJ | g/MJ | g/MJ | g/MJ |
| Renewable Naphtha | [redacted] | [redacted] | [redacted] | [redacted] |
| Yield adjustment | [redacted] | [redacted] | [redacted] | [redacted] |
| Yield adjusted naphtha | [redacted] | [redacted] | [redacted] | [redacted] |
| Electricity | [redacted] | [redacted] | [redacted] | [redacted] |
| Natural gas | [redacted] | [redacted] | [redacted] | [redacted] |
| Net fuel gas | [redacted] | [redacted] | [redacted] | [redacted] |
| GHG Emissions renewable gasoline | 32.90 | 29.93 | 42.63 | 29.51 |

# 4. RENEWABLE GASOLINE TRANSPORT

The renewable gasoline transport emissions are set to the CARBOB transport emissions per table A.1 of the CA-GREET 3.0 CARBOB emissions model:

0.30 $gCO_2e/MJ$.

## 5. Tanks to Wheels

The tank to wheels emissions of the renewable gasoline are set identical to the tailpipe $CH_4$ and $N_2O$ emissions per the table A.4 of the CA-GREET 3.0 CARBOB emissions model:

0.14 gCO2/MJ for $CH_4$ + 0.91 $gCO_2e$/MJ for $N_2O$ = 1.05 gCO2e/MJ

# 6. INDIRECT LAND USE CHANGE

Indirect Land Use Emissions for soybean oil is 29.10 $gCO_2e/MJ$.

Indirect Land Use Emissions for canola oil is 14.50 $gCO_2e/MJ$.

There are no Indirect Land Use Emissions for corn oil.

# 7. SUMMARY

The emissions calculated for the individual stages are summed to determine the fuel cycle CI. The results for the Phillips 66 renewable gasoline pathway are shown in the following table.

**Table 7-1 Carbon Intensity Summary**

| Stage | Emissions, g $CO_2$eq/MJ | | | |
|---|---|---|---|---|
| | Soybean by barge | Soybean by rail | Canola | Corn Oil |
| Renewable Gasoline | 32.90 | 29.93 | 42.63 | 29.51 |
| ILUC | 29.10 | 29.10 | 14.50 | 0.00 |
| Transportation | 0.30 | 0.30 | 0.30 | 0.30 |
| Tank to Wheel | 1.05 | 1.05 | 1.05 | 1.05 |
| Total | 63.35 | 60.38 | 58.48 | 30.86 |